TOPICAL OUTLINE

VIRGINIA GIS REFERENCE BOOK

General Application Name: Public Works/Service Authority

Product/Service/Function Name: Pipe Inventory

P/S/F Description:

One of the most important aspects of the management of water and wastewater infrastructure for a locality is the body of practices termed Asset Management. Asset management addresses the planning, management, use, and maintenance of all asset components that form water and wastewater infrastructure. Forming the backbone of most water and wastewater infrastructure systems is the pipe inventory that represents and accounts for all assets comprising these systems. Good asset management starts with good data and must be based on accurate and complete information from pipe inventories. A pipe inventory describes each element in two asset groups: 1) water, and 2) wastewater. A pipe inventory encompasses the pipes (i.e., mains, laterals) maintained by service authorities, public utility, or public works departments for municipalities, and may also include the related appurtenances (i.e., valves, fittings, meters, etc.). Localities use this information in conjunction with service area information for capital improvement plans, water and sewer infrastructure planning and maintenance, evaluation and rehabilitation, customer service, water quality assessments, and economic development. All localities in Virginia maintain some type of manual record and/or digital database describing and delineating the locations of their water and sewer pipe inventories. Developing a GIS digital representation of this information will allow localities to map existing utility infrastructure and retrieve information for strategic management and planning.

Product/Service/Function_____

1. Spatial Data – Minimum Requirements – Optional Requirements

   A pipe inventory constitutes the linear assets of a water and wastewater system serving a municipality. The spatial data in the GIS should group the utility infrastructure of a locality into distinct water and sewer features. It is important to note a GIS feature is simply an item, like a water main, that is shown on a map and stored in a GIS. Spatial data for water and sewer pipe inventories are comprised of the geographic location of these assets. In general, public utility or public works departments are responsible for the development and maintenance of paper (hardcopy) or digital maps that depict these assets as linear features on a map. With a GIS, municipalities can create a digital representation of these paper maps that is dynamically linked to the attribute information from a digital database by way of a unique number; thereby significantly increasing the access to attribute information and enhancing the efficiency of daily workflows.

   Minimum Requirements

   1. The spatial data representing these assets in a GIS must be line features. The minimum requirements for spatial data include creating digital maps in a GIS of the pipe inventory for water and wastewater assets. At a minimum, the pipe inventories for a municipality should be converted into a standard electronic format compliant with one of the major GIS software platforms.

Optional Requirements
Optional requirements include having the point assets (i.e., appurtenances, pumps, manholes) converted to a GIS format. The utility infrastructure represented as point features in a GIS could include fittings, valves, pumps, manholes and other features that form the utility infrastructure system. With this data, a locality can track all its assets by geographic location and have an automated method for accessing and maintaining pipe inventory information.

2. Attribute Data – Minimum Requirements – Optional Requirements

Attribute data refers to descriptive information associated with geographic features or spatial data. This data is normally stored as fields in a database or spreadsheet, then entered into the GIS and stored in attribute fields linked to the spatial data.

Minimum Requirements
When deciding on the appropriate or required attribute data to include with each asset feature, the first step is to ensure the assets in the water system and the wastewater system are classified. For instance, the minimum GIS features to include in the pipe inventory for a water system are mains and laterals. Many water systems and wastewater systems contain specific classes of mains. For water systems, the main features may be classified as pressure water mains or gravity water mains, while wastewater main features may be classified as sewer, storm water, or combined mains. Therefore, the linear features in the GIS representing these assets should have an attribute field specifying the type of main. In addition, a consistent identification numbering scheme for the water and sewer system pipes needs to be developed, assigned, and captured into the GIS. Overall, the minimum requirements for the attributes to be stored with mains and laterals include:

- Unique ID
- Installation Date
- Material
- Length
- Diameter
- Account ID (laterals only)

In order to link the spatial data (i.e., mains, laterals, valves) in a GIS with the attribute information stored in a digital database, each GIS feature should contain a unique identification number in its attribute table that matches numbers in the digital database. When this is accomplished, the information in the databases can be digitally linked to the GIS features.

Optional Requirements
If it is determined that point asset features are to be collected in the GIS, then attributes can be added to the attribute tables for each type of asset feature collected in the GIS. Examples include:

Valves and Fittings
- Unique ID
- Type
- Manufacturer
- Size

Manholes
- Invert
- Depth

- Diameter
- Condition

3. Data Acquisition Options (integrated with VBMP digital orthos)

   Data about the pipe inventories for localities usually exist in digital and paper format. If digital data is incomplete, pipe inventory information must be gathered manually based on paper sources. This requires collecting data about each asset and completing a manual inventory of water and wastewater infrastructure assets. The key is to start with the spatial data and attributes identified under the minimum requirements and then add more over time. As an example, a locality could begin a pipe inventory project by acquiring data for mains and laterals, and then additional features such as valves and fittings could be added later.

   Data acquisition for pipe inventory mapping can involve three processes: 1) Digitization, 2) CAD Conversion, 3) GPS surveys.

   1. Digitization is the method by which the locations of linear infrastructure assets drawn on source paper maps (i.e., as-built drawings, intersection drawings) are captured in a computer format for a GIS, thereby forming a digital map. If available, paper maps can be taped to a digitizing tablet, then the water and wastewater features are entered into the computer by tracing over the map with a magnetic cursor (similar to a mouse). A scanning machine can also be used to convert the paper maps to digital map images. GIS software is used to view these digital images on the computer screen, and then the features seen on-screen are traced using a computer mouse. At a minimum, the hardcopy maps for a municipality should be converted into a standard format compliant with one of the major GIS software platforms.

   2. Some localities already have existing digital maps delineating the water and wastewater assets in a Computer-Aided Design (CAD) software format commonly used in Engineering Departments. Most GIS software has the functionality to import and convert this data into the appropriate GIS format.

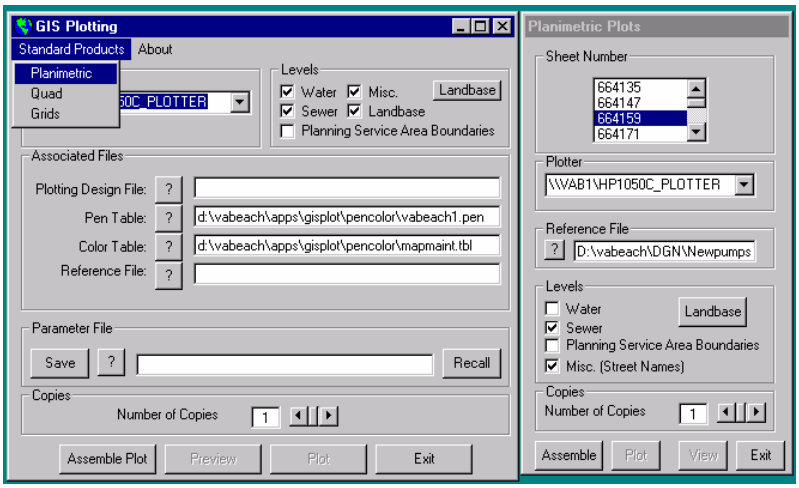
   3. A third option for data acquisition would be to use Global Positioning Satellite (GPS) equipment to precisely locate point features such manholes, fittings, or valves. Then, the linear features (i.e., mains) can be digitized between these points. GPS equipment takes advantage of sophisticated technology to capture the exact latitude/longitude position of features using satellites orbiting the Earth. This option can also be used in conjunction with one of the methods above to more accurately locate existing linear assets in the GIS.

4. Data Conflation Options (integrated with VBMP digital orthos)

   When creating a digitial map through digitization of paper maps, conflation is the process of updating pipe inventory data in a GIS to match the most accurate spatial and attribute sources. If a locality plans on performing this task in-house, it is imperative for the locality to have the necessary source data. Pre-requisite source data includes paper as-built maps, digitally scanned as-built maps, or CAD data. As mentioned previously, the scanned maps can be used as a guide for digitizing the assets in the GIS. To ensure an accurate fit, pipe inventory data can be conflated or matched to actual ground and cultural features visible in the digital orthophotography (i.e., VBMP digital orthos). For example, linear features such as water mains digitized in a GIS could be adjusted to the appropriate location along a road as viewed in the digital orthos. The main caveat to this procedure is the data will only be as accurate as the inherent accuracy of the imagery. If the pipe inventory is created or converted from

as-built sources that are more accurate than the imagery, then a locality may not want to conflate this data to the imagery for fear of degrading the accuracy of the data.

5. GUI/Programming Options



GUI for Map Production

A GUI or Graphical User Interface is the graphics a computer user sees on the computer screen when they run a computer program. Many of the leading GIS software platforms have GUI's that have similar features to Microsoft Word including buttons and toolbars that initiate different processes. Depending on the GIS software platform used to create and maintain the data, a municipality has the ability to develop customized programs that alter the look of the GUI and streamline certain processes. A municipality can develop programs that run within the main graphical window of the GIS software. An example of this would be the development of a program that allows a user to automatically generate intersection drawings of water and wastewater assets, and create standardized map products for its engineering field crews.

6. Internet Functionality and Options

The internet offers an excellent medium for distributing data and information in a public domain. By utilizing the internet, a locality can provide access to utility infrastructure contained in the GIS to any citizen with a computer and internet connection. This functionality can dramatically reduce the time spent answering citizen inquiries concerning utility information and increase employee productivity. Any data stored in a GIS format can be accessed and displayed over the internet using web mapping technology from leading GIS software vendors. A locality must be cognizant of the security issues surrounding the viewing of sensitive data over the internet. Only data deemed suitable for public viewing and that won't compromise the security of a locality's water and sewer system should be included in a mapping website. The best course of action for a locality would be to develop an internal website called an intranet where this data would only be accessible to authorized users found in departments responsible for maintaining and updating the water and wastewater infrastructure data.

7. Minimum Technical Requirements – Optimum Technical Requirements

The following minimum technical requirements apply to the hardware/software configuration recommended to implement and maintain service area mapping in a GIS.

Hardware

- IBM PC or compatible computer
- Windows NT service pack 6a, Windows 2000 service pack 2, Windows XP Home Edition, or Windows XP Professional Edition
- PC with a fast Pentium chip (450 Mhz minimum)

- 128MB RAM minimum
- 10 GB hard drive
- Fast disks (SCSI as opposed to IDE)
- True color monitor with a minimum of 16MB video card
- Paging File (Swap Space) at a minimum of 300MB.

Software
- Windows, Macintosh, or Unix compatible
- GIS (i.e., ESRI, Intergraph, Autodesk)

The following optimum technical requirements apply to the hardware/software configuration recommended to implement and maintain service area mapping in a GIS.

Hardware
- Windows NT service pack 6a or Windows 2000 service pack 2
- PC with a fast Pentium chip (750Mhz or higher recommended)
- 256MB RAM or above
- 20 – 40 GB hard drive
- Fast disks (SCSI as opposed to IDE)
- True color monitor with a minimum of 32 MB video card
- Paging File (Swap Space) at a minimum of 300MB.

Software
- Windows compatible
- ESRI GIS software (consistent with other localities in Virginia)
- Specialized Water and Sewer Modeling software from ESRI business partners

8. Administrative/Management Requirements

Several issues must be addressed when determining the management requirements for pipe inventory data in a GIS. Initially, a locality must decide whether to develop and maintain the GIS data by hiring a consultant or with in-house staff. This decision will depend on factors such as budgetary issues, staff expertise, staff availability, scheduling, and technical resources of the locality. Due to the intense demands on staff time, the normal course of action for many localities in Virginia is to hire consultants to convert their pipe inventories from source drawings and CAD data, and then internally maintain and update this GIS information indefinitely.

If a locality decides to internally maintain pipe inventory data in a GIS, then personnel must be identified for the project. Conducting a strategic plan up front will allow a locality to identify current staff that may aid in the development of the GIS. A locality should start by selecting staff members with an interest and background in geography, mapping, computers, or engineering. Personnel with this kind of experience usually understand the basic concepts behind mapping spatial data and will probably learn GIS much faster than other employees. Personnel from planning, economic development, engineering, public works, and public utility departments are ideal candidates for GIS training. Ideally, a locality will designate staff members from the departments responsible for utility maintenance (i.e., Public Utility or Public Works) to manage the effort.

Several types of staff will be needed to develop GIS data and maintain the system. First, a qualified manager with experience working with spatial utility data should be assigned to oversee the development of a municipality's pipe inventory data and guide the policies governing the use of this

data. For a locality in the early stages of GIS development and with little GIS expertise, this means hiring a GIS manager from external sources. Second, selected staff members from the departments identified above should be trained to complete tasks commonly performed in a GIS. This includes digitizing maps, creating GIS data layers, assigning attributes from digital databases to GIS features, and creating map products for local planning, maintenance, and reporting purposes. Overall, a locality will need one GIS manager and 2-4 staff members dedicated to maintaining the GIS data depending on the density of the water and wastewater infrastructure. There should always be constant interaction between the staff members maintaining the pipe inventory assets in the GIS and those departments responsible for maintaining the pipe inventory assets in the real world.

9. Cost – Cost/Benefit

The costs associated with pipe inventory development and maintenance will constitute a very large portion of the overall costs a locality will need to allocate for GIS data conversion to fulfill the data requirements of the Public Works/Service Authority General Application. In fact, most of the costs associated with developing GIS data for this application will involve the conversion of data for this Pipe Inventory sub-application described in this discussion. While the costs associated with developing the GIS data for this application can widely vary depending on the spatial extent of the utility infrastructure and the spatial extent of a municipality, these costs will be relatively high compared to other GIS costs. It is important to investigate the "bottom line" costs of implementing any GIS project to determine the financial justification for such an endeavor, and to estimate the adequate level of funding required to develop and implement a comprehensive GIS. Costs related to pipe inventory development and maintenance can be separated into two phases:

- Data Acquisition (Development) Costs
- Data Operational (Maintenance) Costs

Development costs will depend on the data acquisition and conflation methods chosen. Cost estimates for development will also vary depending on the sources and methodology used, but the total cost to create a pipe inventory map for GIS generally falls between $150,00 - $1,500,000. This cost is dramatically reduced if a locality has existing digital CAD data. It is important to note these costs vary based on the number of pipe inventory assets and the number of attributes to be added to the GIS data. Additional start-up costs for a locality may involve investing in the necessary hardware and software, if needed. Hardware costs include a dedicated computer server for the GIS and PC's for the staff assigned to work on the GIS. Suitable computer servers can range in cost from $10,000 - $50,000, depending on the technical specifications like processor speed and memory. PC's that meet the minimum technical requirements to operate GIS software range in cost from $800 - $2000. GIS software costs will vary depending on the software package purchased. Current prices (per copy of software) for GIS software are $1000 - $1500 for low-end products, $4000- $5000 for middle-end products, and $10,000 - $12,000 for high-end products.

Provided below is a summary of the cost range for common tasks performed during a GIS implementation of pipe inventory information, assuming the GIS program is just beginning:

Needs Analysis – Needs Assessment; Data Survey; Management Plan; System Implementation Plan.....	$50,000 - $100,000
Hardware – 1 Server and 2 - 4 Workstations (if needed).....	$10,000 - $50,000
Software – GIS Software (3 - 5 licenses).....	$20,000 - $50,000
Peripherals – Plotters; Printers; Scanners; Digitizers; GPS Equipment (if needed).....	$20,000 - $50,000
Staffing (Annual) – 1 GIS Manager, 2- 4 GIS Technicians	$50,000 - $200,000

Training	$10,000 - $40,000
Pipe Inventory Data Development	$150,000 - $1,500,000
Application Development for Pipe Inventory Analysis	$10,000 - $150,000
Future Consulting	$50,000 - $500,000

After the implementation is complete, a municipality must enact operational procedures to ensure the currency of the data is protected through daily maintenance of the pipe inventory information in the GIS and accompanying digital databases. Operational costs associated with data maintenance will be the amount of staff time dedicated to this effort. Depending on the size, a locality should have at least 2 staff members working full-time updating water and wastewater infrastructure changes, so the costs would be the salaries of these staff members.

Quantifying the major GIS benefits is very difficult, but there are some benchmark studies that document productivity improvements and cost savings produced by GIS. One of the studies frequently referenced for cost and benefit data related to GIS is the *Joint Nordic Project – Community Benefit of Digital Spatial Information* cited in *The GIS Book (George B. Korte, 1997)*. This study collected information on the costs and benefits of 16 GIS projects. The following findings offer general estimate ratios for benefit/cost (B:C) returns:

- GIS is used only for digital mapping of service area information – **1:1** return
- GIS used for planning and engineering tasks – **2:1** return
- All paper maps converted to digital maps – **3:1** return
- GIS is used to create and maintain all spatial data – **4:1** return
- GIS data stored in one database and shared by all user departments – **4:1** return
- An automated system in GIS for localities with poor quality maps and maintenance procedures – **7:1** return
- GIS used for spatial analysis – **10:1** return

10. Standards/Guidelines Summary

In Virginia, many localities have digitized their as-built maps and conflated this data to digital orthophotography. In essence, the data is only as accurate as the source it came from, which can include paper maps and/or CAD data. The majority of municipal paper maps are developed at scales between 1 inch = 200 feet and 1 inch = 400 feet. Digital maps based on these sources will only be as accurate as the National Map Accuracy Standards (NMAS) for data sources at these scales. There are no pre-defined accuracy requirements for GIS pipe inventory data, so accuracy specifications usually depend on a municipality's requirements and day-to-day information needs. It is recommended that a municipality utilize digital orthophotography as a base map and a source for geo-referencing maps. In the State of Virginia, many municipalities geo-reference their GIS data in the Virginia State Plane Coordinate System (NAD 1983).

11. Startup Procedures/Steps

Building a successful GIS database containing pipe inventory data should consist of several startup procedures including planning the project, communicating the project plan to all interested parties, gathering data sources and resources, setting achievable milestones, and gaining manager support. The up-front planning of the conversion effort must accomplish the following:

- Establish goals and strategies

- Perform a needs assessment with end users in the Public Utility and Public Works Departments
- Determine data requirements based on the needs analysis
- Prepare a budget and project timeline
- Determine staff to maintain the data

Based on the cost estimates for outsourcing the GIS work to a consultant, the in-house staff expertise, and GIS budget, a locality must determine whether to perform the work internally or have a consultant complete the work. Once this decision is made, a locality must invest in the hardware and software needed to support the GIS. The number of computers and number of software packages to purchase should be specified in the needs analysis. Many localities in Virginia have hired outside consultants to prepare the needs analysis that will guide the future pipe inventory GIS such as the City of Virginia Beach.

12. Estimated Time Line and/or Implementation (stand alone) schedule

Estimating the time line or schedule for a GIS pipe inventory implementation project will certainly depend on a number of factors specific to a municipality, including:

- Size of the municipality
- Density of data sources (paper or CAD) covering the municipality
- Methodology of conversion (i.e., digitization versus CAD conversion)
- Staff resources of consultant performing the work
- Funding

For most rural localities, a reasonable estimate for the development of pipe inventory data is from 1 – 2 years, assuming a consultant is hired to perform the work. More urban localities that have much denser maps will need roughly 2-3 years to complete the work. Of course, these timelines would increase if a locality decides to complete the project in-house. Once a digital pipe inventory map is developed for the locality, time must be allocated to update the GIS for changes occurring to water and wastewater assets in the locality. An example of this would be a new subdivision being built with new utility infrastructure being developed. New water and wastewater mains and laterals would have to be added to the GIS. In localities with low growth rates and minimal suburban sprawl, maintenance of the pipe inventory data in the GIS would be limited to a maximum of 1-2 weeks of staff time per month. In localities experiencing high growth rates, weekly maintenance will be required to keep the information up-to-date in the GIS and digital databases.

13. Best Practice Examples in Virginia

Several municipalities have converted their pipe inventory assets into a GIS. Notable examples include the City of Virginia Beach's Automated Mapping and Facilities Management (AM/FM) GIS. The City of Virginia Beach, Department of Public Utilities is taking advantage of GIS technology in the implementation of an Automated Mapping and Facilities Management (AM/FM) system with the support and guidance of a partnership team composed of representatives from the City's Departments of Public Utilities, Public Works, and the primary contractor. The City uses this data for its Sanitary Sewer Evaluation and Rehabilitation program that identifies and determines the short and long-term maintenance and rehabilitation needs for the entire sanitary sewer system, including the development of a strategic plan to inventory, prioritize, schedule, and identify funding needs for their maintenance and rehabilitation efforts. Other current applications of the pipe inventory data contained in the City's GIS include:

- Map Maintenance
- Asset Inventory and Evaluation
- Work Order Processing
- Link to Customer Records
- Engineering Model Integration
- Miss Utility Field Location Services

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